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Investigation of Leaks in Fiberglass-Reinforced Pressure Vessels by Direct Observation of Hollow Fibers in Glass Cloth*

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Abstract

A simple method of visual observation of hollow fibers within fiberglass cloth has been developed. This visualization can aid in determining the contribution these fibers make toward leaks observed in fiberglass-reinforced epoxy resin pressure or vacuum vessels. Photographs and frequency data of these hollow fibers are provided.

Fiberglass-reinforced epoxy resin (typified by the commercial material designated N.E.M.A. grade G-10) has found widespread use as a mechanical support and electrical insulator. The electromagnetic coils found in fusion reactors and high-energy physics accelerators are typical examples. It is common for the material to act as a pressure or vacuum vessel in these applications. However, the integrity of such barriers may be compromised by the presence of hollow fibers within the fiberglass cloth.

The existence of hollow fibers in fiberglass cloth was originally proven by R.J.B. Hadden and A. Kirk[1]. In their paper, they provided photographs of a single, hollow fiber. Here, I provide further evidence of the existence of hollow bores within the glass fibers and offer a simple method for estimating the frequency of these bores.

A small area of fiberglass cloth is saturated with a fluid with a refractive index similar to that of the fiberglass. The fluid must be kept in a confined area by capillary action, such as is produced by sandwiching the fiberglass cloth between a slide and a cover slip. This procedure effectively removes the fibers from view, and the air-filled bores become plainly visible. To illustrate this effect, Fig. 1 shows an intersection of two bundles of fibers while Fig. 2 shows the same area after the introduction of the fluid.

A second method involves the use of a fluid with a slightly different index of refraction than that of the fiberglass cloth. (I used a fluid with an index approximately .002 less than the index of refraction of the fiberglass.) The air in the bores is still plainly visible, and the glass of the fibers can also be faintly seen. This produces an image of the glass fibers and the hollow bores simultaneously. Figure 3 is a photograph of this effect on a different section of fiberglass cloth.

Both of these methods provide a means to optically measure the diameter of the bores within the fibers. My observations indicated that the diameters range from 1 to 2.5 microns. Another benefit of immersing an entire bundle of glass fibers is that a frequency count of the hollow bores can be taken. In the fiberglass cloth used here, each strand contains 816 fibers of which 1.5 to 2.6 % were found to be hollow in any cross section. Although I have observed ends of the hollow bores, neither of these methods can be readily used to determine the maximum length of a hollow bore which has been measured at over 86 cm[1]. The observed ends of the hollow bores suggest that they are formed by air bubbles trapped in the molten glass. They also indicate that only when both ends of a hollow bore have been cut open during machining will leakage occur. A bore with only one end open may produce a virtual leak to a vacuum. To produce a continuous leak, a bore must span the pressure wall and be cut on both ends. Epoxy paints have been successfully used to seal machined surfaces of pressure vessel walls.

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1. R.J.B. Hadden and A. Kirk, "Leakage Within Glass-Fibre Reinforced Epoxy Resin Laminates," (Harwell, Berkshire, 1960).

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Figure 1. Intersection of two bundles of fibers. (65x magnification)
Figure 2. Same intersection immersed in refractive index fluid. (65x magnification)
Figure 3. Intersection of two fiber bundles in fluid. (100x magnification)
(The thin black lines are the hollow bores.)

Figure 1.

Figure 2.

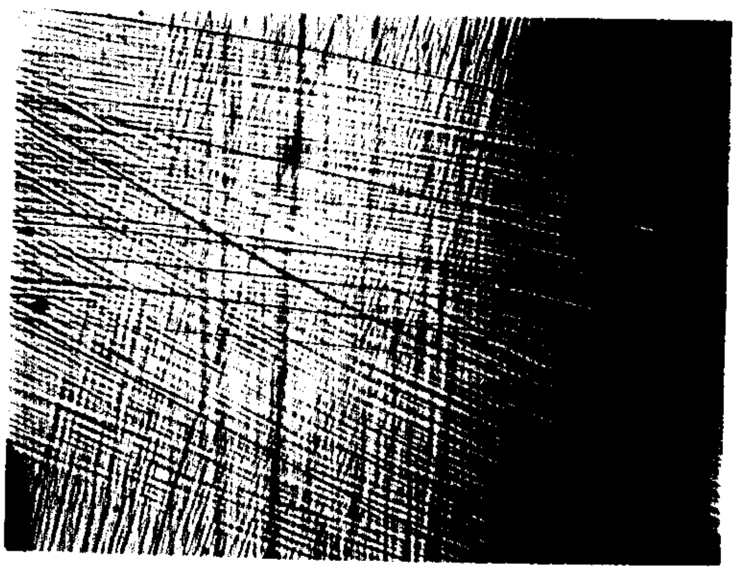

Figure 3.